LEEDS & NORTHRUP CO.
800-19 NEW LOUDON RD.
LATHAM, NEW YORK

4395
VOLTAGE DIVIDER
CALIBRATION PROCEDURE

LEEDS & NORTHRUP

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CALIBRATION PROCEDURE

	Range	Limit of Error
Voltage Division	1 Part in 100,000 to 100,000 Parts in 100,000	±1 Main Slidewire Division (0.001% of Input)
Decades	9 x (10,000 + 1000 + 100)	
Slidewire	0 to 100 Main Divisions (200 Scale Divisions)	
Input Resistance	100,000 Ohms	±0.1%
Voltage Rating	200 v Continuous 300 v Up to 1/2 Hour	
Galv. Sensitivity Keys	Low, Medium, High	

1.0 CALIBRATION INTERVAL

1.1 The instrument should be checked before it is put into service and at intervals of six months.

1.2 Environmental shocks or wide fluctuations of any sort require a check to be made even though the regular interval has not elapsed.

2.0 EQUIPMENT REQUIRED

—Six Dial Universal Ratio Set, L&N Co. Cat. 4393
—100,000 Ohm Resistance Standard, L&N Co. Cat. 4045-B
—Electronic Null Detector, L&N Co. Cat. 9834
—2 Resistance Boxes, L&N Co. Cat. 4775
—Tapping Key, L&N Co. Cat. 3702
—1.5 Volt Battery, No. 6 Dry Cell
—Solid Copper Clip Connector, Mueller Electric Co. #45C with #47 Insulator

3.0 PRELIMINARY NOTES

3.1 Read entire procedure before beginning check.

3.2 All equipment should be permitted to stabilize in the test area for 12 hours prior to calibration.

3.3 The Universal Ratio Set is referred to as the URS throughout the procedure.

3.4 GENERAL

3.4.1 The procedure consists of a step by step operation for obtaining the correction data for the 4395.

3.4.2 The procedure is measuring the 100,000 ohm nominal input resistance and the relationship of each step of each dial to the input resistance.

3.4.3 The procedure determines if they are within the specified tolerances.

3.4.4 Calibration reports, if issued, must contain pertinent values and entered on a form as shown in Fig. 7.

3.4.4.1 Calibration reports should contain an identification of the instrument such as the serial number.

3.4.4.2 Date of report, temperature and humidity at time of calibration should be listed.

3.4.4.3 Signature of person performing the calibration should be included.

3.5 CALIBRATING INSTRUMENTS

3.5.1 The URS and a 100,000 ohm N.B.S. resistance standard are to be used as the major calibrating instruments.

3.5.2 All major calibrating instruments should have been calibrated within a year by the National Bureau of Standards or other qualified agency.

3.5.3 The URS is a ratio device described in Directions 177156.

3.5.4 The 100,000 ohm N.B.S. resistance standard is supplied with an L&N Co. calibration report.

3.5.4.1 Exact resistance is given to within ±0.005% limit of error.

3.5.5 After a history has been established for the calibrating instruments in 3.5.1, the National Bureau of Standards may report on their accuracies to ±0.001% or better.

3.6 OPERATING CONDITIONS

3.6.1 Reliable calibration data require a competent operator and suitable atmospheric conditions.

3.6.1.1 All instrument surfaces must be clean and dry.

3.6.1.2 The operator's experience in precise measurements should be

such as to enable him to detect any inconsistencies and to recognize any abnormal behavior of the apparatus or circuit.

3.6.2 The calibration should be performed in a room in which the temperature is controlled at 25C ±1C and the relative humidity is less than 50%.

3.6.2.1 The room should be free from excessive vibration.

3.6.2.2 The 120 volt 60 cycle power supply should be free from excessive fluctuations.

3.7 TABULATION OF DATA

3.7.1 The readings of the URS should be tabulated; the calculations performed; and the results listed on worksheets as shown in Figs. 3, 4 and 5.

3.7.2 The following should be included in the tabulation of the data:

—Serial or plant identification numbers of the instruments used.
—Temperature at which the calibration was performed.
—Date of the calibration.
—Identification of the operator.
—The corrections of the URS.
—The calibration report value of the resistance standard.

4.0 DETAIL PROCEDURE

4.1 CHECKING THE INPUT RESISTANCE

4.1.1 MAKING THE SETUP

4.1.1.1 Make connections as shown in the diagram in Fig. 1 for measuring the input resistance.

4.1.1.2 Use #14 or heavier bare solid copper wire for making the connections.

4.1.1.3 The conductors should be insulated by air.

4.1.1.4 The detector lead is an exception and is a two conductor shielded leadwire supplied with the 9834 Null Detector.

4.1.1.5 The URS, 4395 and 9834 cases should be grounded.

4.1.1.6 Shielding is not ordinarily necessary.

4.1.1.6.1 Should disturbing pickup be encountered, additional shielding will be necessary. Reference should be made to Directions 177156.

4.1.1.7 The No. 2 detector lead is extended by approximately one foot

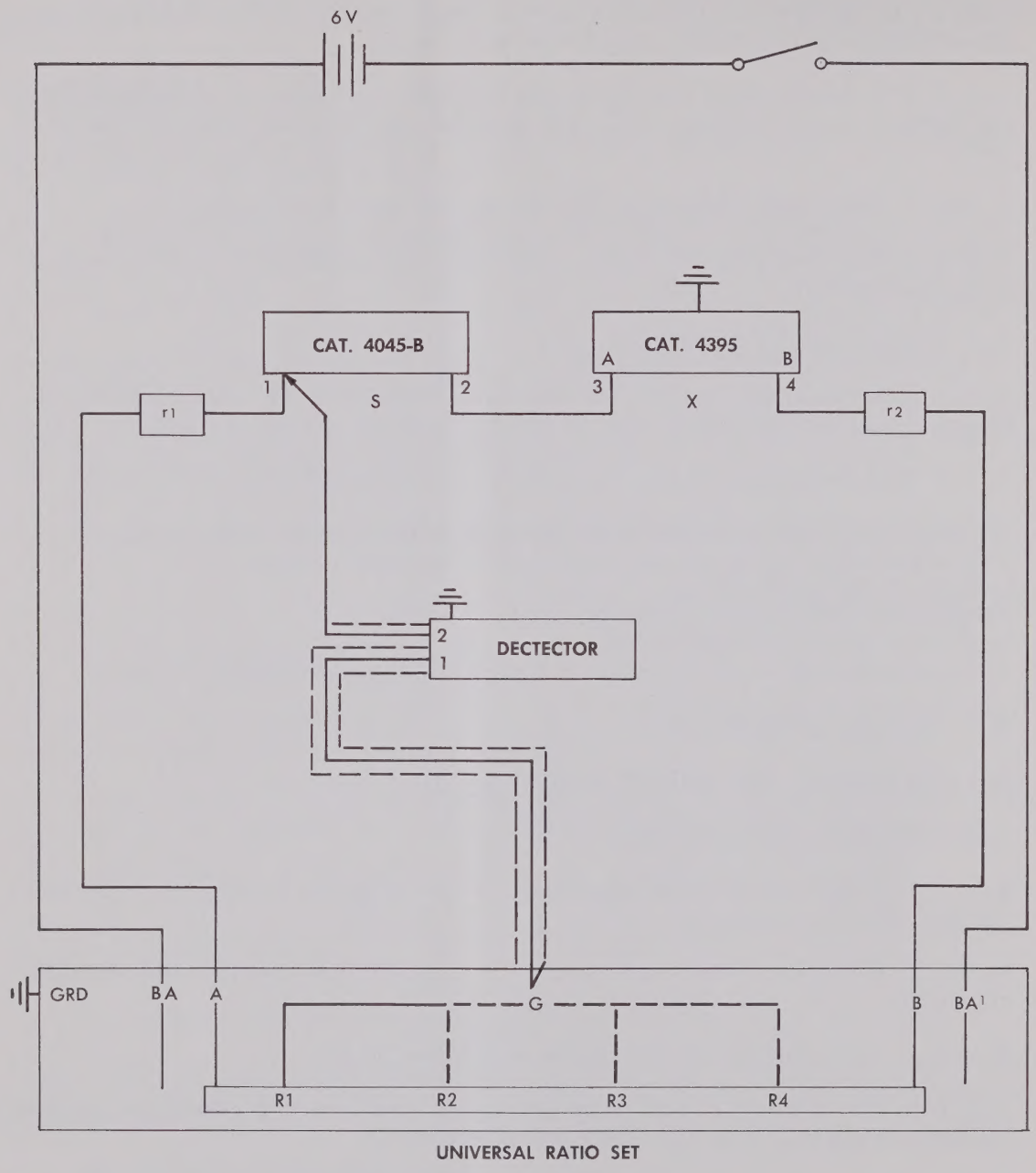

Fig. 1—Schematic diagram for input resistance checks.

of insulated stranded copper wire for making temporary connections.

4.1.1.8 Connect the Mueller clip to the No. 2 detector lead.

4.1.1.9 Resistances r_1 and r_2 are to be 50 ohms each.

4.1.1.9.1 They need not be very accurate but must be very stable for the period during which the measurement is made.

4.1.1.9.2 They are inserted in the upper arms of the bridge so that the low end and high end readings may be obtainable on the URS for all of the ratios which will be set up in the lower arms of the bridge between "X" and "S".

4.1.2 MEASURING THE INPUT RESISTANCES

4.1.2.1 Connect the Mueller clip successively to points 1, 2, 3, and 4 as shown in Fig. 1.

4.1.2.2 Balance the URS at the corresponding settings of R_1, R_2, R_3 and R_4.

4.1.2.3 Record the URS readings for each measurement on the worksheet as in Fig. 3.

4.1.2.4 Typical readings are 000.518, 1055.554, 1055.556 and 2110.593.

4.1.2.5 Apply the URS corrections.

4.1.2.6 Corrected values are 000.518, 1055.552, 1055.554 and 2110.592.

4.1.2.7 Calculate R_2-R_1, R_4-R_3, and the ratio $\frac{R_4-R_3}{R_2-R_1}$.

4.1.2.8 Enter this ratio value and the correct resistance of the "S" resistance standard in the equation,

$$X = \frac{R_4 - R_3}{R_2 - R_1} S \text{ and solve for X.}$$

Example:

$$X = \frac{2110.592 - 1055.554}{1055.552 - \quad 0.518} \times 99,996.9 = 99,997.3 \text{ ohms.}$$

4.1.2.9 The formula provides the input resistance of the 4395 within the sum of the limits of error of the URS and the resistance standard.

4.2 CHECKING THE RATIOS

4.2.1 MAKING THE SETUP

4.2.1.1 Make the connections the same as in Fig. 2 for checking the ratios.

4.2.1.2 The general considerations are the same as described in 4.1.1.

4.2.1.3 Reduce the values of r_1 and r_2 to 5 ohms each.

4.2.1.4 Connect the detector successively to points A, C, and B of the 4395.

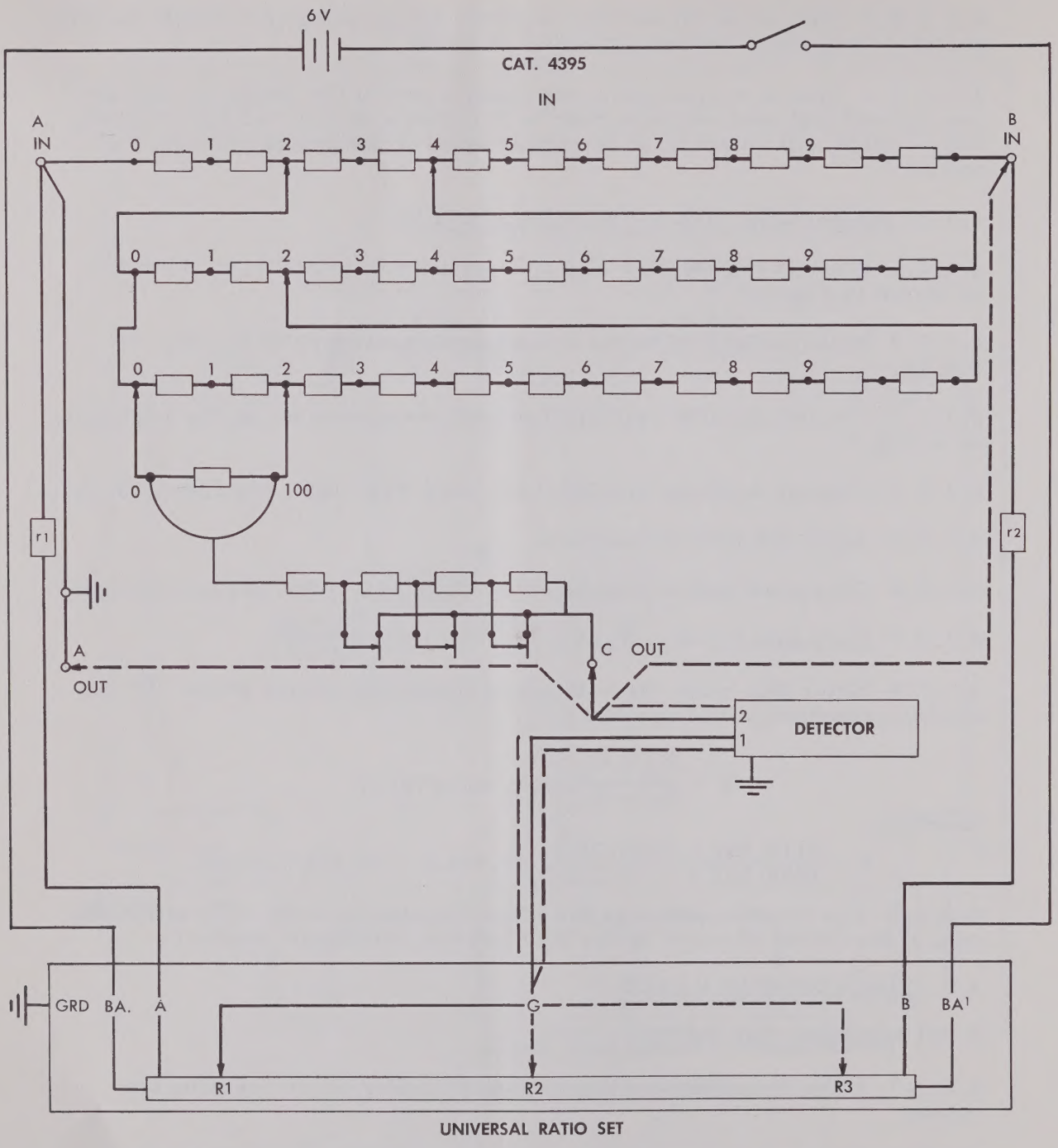

Fig. 2—Schematic diagram for ratio checks.

4.2.1.5 Set all dials on zero.

4.2.1.6 Balance the URS at the corresponding settings of R_A, R_C, and R_B.

4.2.1.7 Record the URS readings on a worksheet as shown in Fig. 3.

4.2.1.8 Typical readings are 000.097, 000.098, and 2111.013.

4.2.1.9 With the X 1000 dial set on 9, perform the same procedure.

4.2.1.10 Typical readings are 000.097, 190.077, and 2111.013.

4.2.1.11 List the URS corrections for the settings in each of the R_A, R_C, and R_B measurements.

4.2.1.12 Apply these corrections to the readings.

4.2.1.13 Enter the corrected R_A, R_C, and R_B readings on the worksheet.

4.2.1.14 Typical values are 000.097, 000.098, and 2111.013 for the 0 setting on the X 1000 dial.

4.2.1.15 For the 9 setting on the X 1000 dial, typical readings are 000.097, 190.078, and 2111.013.

4.2.1.16 Calculate $R_C - R_A$, $R_B - R_A$ and the ratio $\frac{R_C - R_A}{R_B - R_A}$.

4.2.1.17 Enter these values on worksheet as in Fig. 3.

4.2.1.18 The nominal ratios are entered on worksheet as in Fig. 3.

4.2.1.19 Subtract the nominal ratios from the actual ratios to obtain the ratio errors.

4.2.1.20 Enter these figures on the worksheet as in Fig. 3.

4.2.2 Repeat sections 4.2.1.4 through 4.2.1.20 for each setting from 1 to 9 of the X 10,000 decade.

4.2.2.1 With the X 1000 dial set on 9, set all other dials on 0.

4.2.2.2 Repeat sections 4.2.1.4 through 4.2.1.20.

4.2.2.3 List the ratio errors for each setting of the X 10,000 decade.

4.2.2.4 Set the X 10,000 decade dial on 9.

4.2.2.5 Set all lower decade dials at their maximum settings.

4.2.2.6 Repeat sections 4.2.1.4 through 4.2.1.20.

Dial Settings	Readings			4393 Corrections			Corrected Readings							PPM
10,000	RA	RC	RB	RA	RC	RB	RA	RC	RB	RC-RA	RB-RA	RC-RA / RB-RA	Nominal Ratio	Ratio Error
0-0-0-0	000.097	000.098	2111.013	.0000	-.0001	-.0004	000.097	000.098	2111.013	000.001	2110.916	.000000	.000000	—
0-9-0-0	↑	190.077	↑	↑	+.0007	↑	↑	190.078	↑	189.981	↑	.089999	.090000	-1
1-0-0-0		211.190			-.0005			211.190		211.092		.100000	.100000	—
1-9-0-0		401.170			-.0006			401.169		401.072		.189999	.190000	-1
2-0-0-0		422.281			-.0007			422.285		422.183		.200000	.200000	—
2-9-0-0		612.261			-.0002			612.259		612.162		.289998	.290000	-2
3-0-0-0		633.372			-.0002			633.373		633.275		.300000	.300000	—
3-9-0-0		823.352			-.0004			823.352		823.255		.389999	.390000	-1
4-0-0-0		844.462			-.0007			844.461		844.364		.399999	.400000	-1
4-9-0-0		1034.442			-.0018			1034.440		1034.343		.489997	.490000	-3
5-0-0-0		1055.557			-.0019			1055.555		1055.458		.500000	.500000	—
5-9-0-0		1245.537			-.0014			1245.536		1245.439		.589999	.590000	-1
6-0-0-0		1266.648			-.0018			1266.646		1266.549		.599999	.600000	-1
6-9-0-0		1456.628			-.0011			1456.627		1456.530		.689999	.690000	-1
7-0-0-0		1477.741			-.0012			1477.740		1477.643		.700000	.700000	—
7-9-0-0		1667.721			—			1667.721		1667.624		.790000	.790000	—
8-0-0-0		1688.832			-.0005			1688.832		1688.735		.800001	.800000	+1
8-9-0-0		1878.812			-.0004			1878.812		1878.715		.890000	.890000	—
9-0-0-0		1899.924			-.0003			1899.924		1899.827		.900001	.900000	+1
9-9-0-0		2089.904			—			2089.904		2089.807		.990000	.990000	—
9-9-9-100	000.097	2111.012	2111.013	.0000	-.0004	-.0004	000.097	2111.012	2111.013	2110.915	2110.916	1.000000	1.000000	—

OVERALL RESISTANCE CHECK

Readings				4393 Corrections				Corrected Readings			
R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4
000.518	1055.554	1055.556	2110.593	—	+.002	+.002	-.001	000.518	1055.552	1055.554	2110.592

$$R \pm N = \frac{R4 - R3}{R2 - RT} \times S = \frac{2110.592 - 1055.554}{1055.552 - 000.518} \times 99,996.9 = 99,997.3 \text{ Ohms}$$

S = Lab. Tool #2496 = 100,000 Ohms Nominal −0.0031% Correction = 99,996.9 Ohms.

Fig. 3—Sample Worksheet A.

4.2.2.7 Typical values are shown on worksheet, Fig. 3.

4.2.2.8 For the X 1000 decade, repeat sections 4.2.1.4 through 4.2.1.20.

4.2.2.9 Typical values are shown on worksheet, Fig. 4.

4.2.2.10 For the X 100 decade repeat sections 4.2.1.4 through 4.2.1.20.

4.2.2.11 Omit the sets of readings with the next lower dial set on maximum for all except the 9 X 100 setting.

4.2.2.12 Typical values are shown on worksheets, Fig. 4 and Fig. 5.

4.2.3 Each main division of the slidewire is checked similarly.

4.2.3.1 Typical values are shown in worksheet, Fig. 5.

4.2.4 Make a set of curves as shown in Fig. 6, which show the errors for each setting of the dial, (corrections are numerically and algebraically the same).

Dial Settings	Values							PPM Ratio Errors	
X 1000	RA	RC	RB	RC-RA	RB-RA	RC-RA / RB-RA	Nominal Ratio	In Decade	In Total
0-0-0-0	000.097	000.098	211.186	.001	211.089	.000005	.000000	+5	—
0-0-9-0	↑	19.097	↑	19.000	↑	.090009	.090000	+9	+1
0-1-0-0		21.207		21.110		.100005	.100000	+5	—
0-1-9-0		40.206		40.109		.190010	.190000	+10	+1
0-2-0-0		42.317		42.220		.200010	.200000	+10	+1
0-2-9-0		61.316		61.219		.290015	.290000	+15	+2
0-3-0-0		63.423		63.326		.299997	.300000	−3	—
0-3-9-0		82.422		82.325		.390001	.390000	+1	—
0-4-0-0		84.532		84.435		.399997	.400000	−3	—
0-4-9-0		103.531		103.434		.490002	.490000	+2	—
0-5-0-0		105.642		105.545		.500002	.500000	+2	—
0-5-9-0		124.641		124.544		.590007	.590000	+7	+1
0-6-0-0		126.751		126.654		.600002	.600000	+2	—
0-6-9-0		145.750		145.653		.690008	.690000	+8	+1
0-7-0-0		147.858		147.761		.699993	.700000	−7	−1
0-7-9-0		166.857		166.760		.789999	.790000	−1	—
0-8-0-0		168.968		168.871		.799999	.800000	−1	—
0-8-9-0		187.967		187.870		.890004	.890000	+4	—
0-9-0-0		190.077		189.980		.899999	.900000	−1	—
0-9-9-0		209.076		208.979		.990004	.990000	+4	—
0-9-9-100	000.097	211.185	211.186	211.088	211.089	.999995	1.000000	−5	—

Cat. 4045-B	100,000Ω Std. Resistor	Lab. Tool 2496
Cat. 4393	Universal Ratio Set	Lab. Tool 4158
Cat. 4395	Precision Voltage Divider	Insp. Tool 217
Cat. 4834	Electronic Null Detector	Lab. Tool 3907

Fig. 4—Sample Worksheet B.

Dial Settings	Values							PPM Ratio Errors	
X 100	RA	RC	RB	RC-RA	RB-RA	RC-RA / RB-RA	Nominal Ratio	In Decade or Slidewire	In Total
0-0-0-0	000.097	000.098	21.207	.001	21.110	.000050	.000000	+50	—
0-0-1-0		2.208		2.111		.100000	.100000	—	
0-0-2-0		4.319		4.222		.200000	.200000	—	
0-0-3-0		6.430		6.333		.300000	.300000	—	
0-0-4-0		8.541		8.444		.400000	.400000	—	
0-0-5-0		10.652		10.555		.500000	.500000	—	
0-0-6-0		12.763		12.666		.600000	.600000	—	
0-0-7-0		14.874		14.777		.700000	.700000	—	
0-0-8-0		16.985		16.888		.800000	.800000	—	
0-0-9-0		19.096		18.999		.900000	.900000	—	
0-0-9-100	000.097	21.206	21.207	21.109	21.110	.999952	1.000000	-48	—
Slidewire									
0-0-0-0	000.098	000.099	002.207	000.001	2.109	.000474	.000000	+474	—
0-0-0-10		000.307		000.209		.099099	.100000	-901	-1
0-0-0-20		000.520		000.422		.200095	.200000	+95	—
0-0-0-30		000.733		000.635		.301090	.300000	+1090	+1
0-0-0-40		000.944		000.846		.401138	.400000	+1138	+1
0-0-0-50		001.152		001.054		.499763	.500000	-237	—
0-0-0-60		001.363		001.265		.599810	.600000	-190	—
0-0-0-70		001.574		001.476		.699858	.700000	-142	—
0-0-0-80		001.786		001.688		.800379	.800000	+379	—
0-0-0-90		001.997		001.899		.900427	.900000	+427	—
0-0-0-100	000.098	002.206	002.207	002.108	2.109	.999526	1.000000	-474	—

Fig. 5—Sample worksheet C.

4.2.4.1 The errors for each setting of the X 10,000 and X 1,000 decade dials differ slightly with different positions to the next lower dial due to changes in the shunting effect.

4.2.4.2 An interpolation may be made between the error with the next lower dial at 0 and with it at 9 in order to obtain a correction. Corrections obtained as the result of this interpolation are strictly approximations. The sum of the errors (corrections) picked off these curves will be the overall error (correction) for any given combination of the settings.

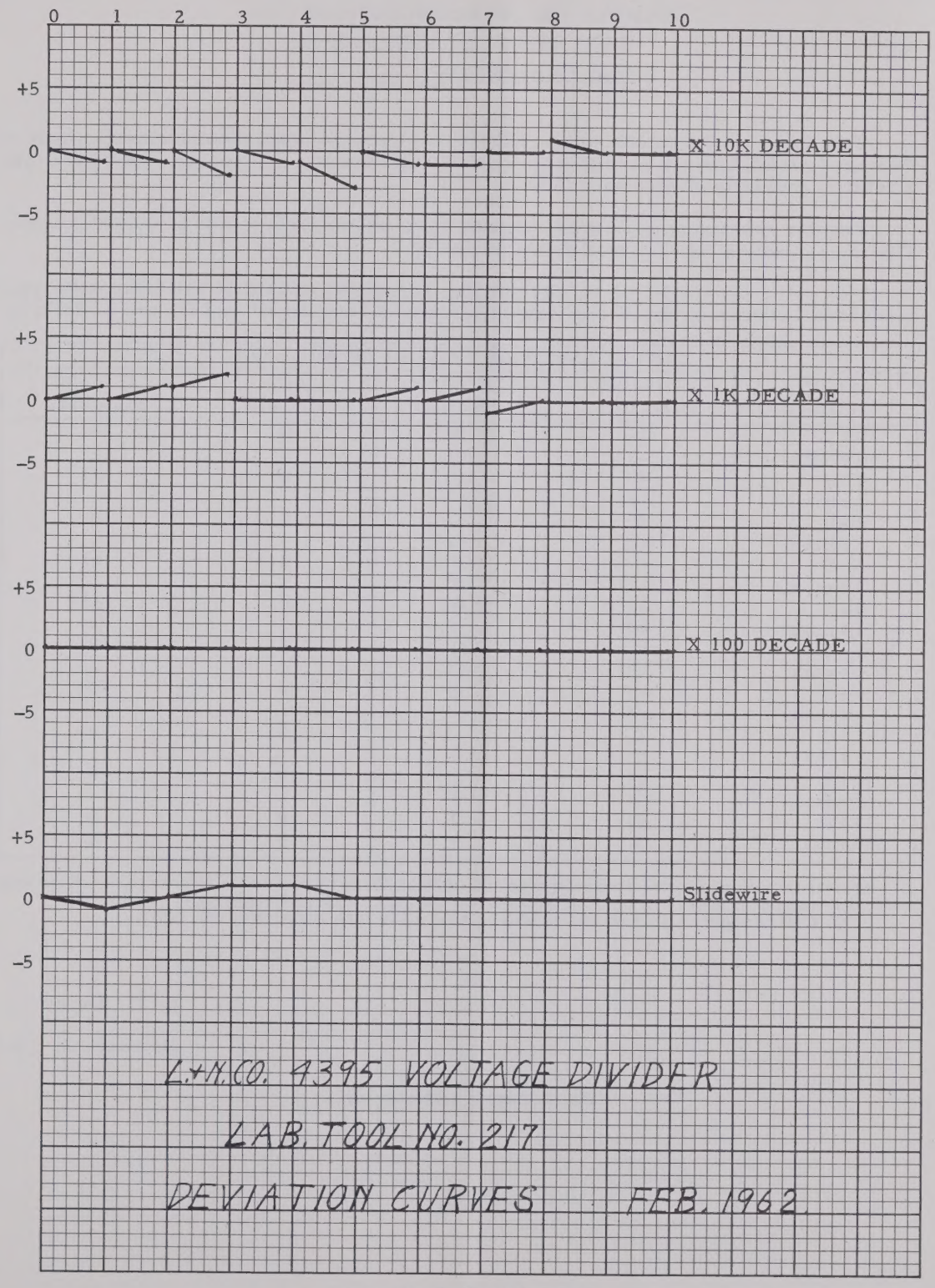

Fig. 6—Sample deviation curves.

SAMPLE CALIBRATION REPORT FOR
CAT. 4395 VOLTAGE DIVIDER
SERIAL NUMBER_____

The data incorporated in this report was secured from measurements made in February, 1962 in an air conditioned room maintained at a temperature of 25±1C and a relative humidity of less than 50%.

The d-c resistance measured between input terminals A and B is 99,997.3 ohms. This measurement is accurate within ±0.002%.

The ratio errors in parts per million for the various dial settings, with input measured between A and B and output measured between A[1] and C, are as follows:

RATIO ERROR IN PARTS PER MILLION				
Dial* Settings	X10,000 Decade	X1000 Decade	X100 Decade	0 - 100 Slidewire
0+0	0	0	0	0
0+max.	-1	+1	-	-
1+0	0	0	0	-1
1+max.	-1	+1	-	-
2+0	0	+1	0	0
2+max.	-2	+2	-	-
3+0	0	0	0	+1
3+max.	-1	0	-	-
4+0	-1	0	0	+1
4+max.	-3	0	-	-
5+0	0	0	0	0
5+max.	-1	+1	-	-
6+0	-1	0	0	0
6+max.	-1	+1	-	-
7+0	0	-1	0	0
7+max.	0	0	-	-
8+0	+1	0	0	0
8+max.	0	0	-	-
9+0	+1	0	0	0
9+max.	0	0	0	0

*First figure in column indicates reference dial setting. Second indication in column refers to the next lower dial being set either on zero or on its maximum setting, all other dials being set on 0.

The figures given in the table above are accurate to within ±0.005%.

L. C. Fryer

October 22, 1963

Fig. 7—Sample calibration report.

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